CHAPTER 3
REGIONAL GEOLOGIC AND SITE RECONNAISSANCE INVESTIGATIONS

3-1. General. Regional geologic and site reconnaissance investigations are made to develop the project regional geology and to scope early site investigations. The required investigation steps are shown in figure 2-1. The initial phase of geologic investigations is a thorough survey of available information. Information on topography, geology and geologic hazards, surface and ground-water hydrology, seismology, and soil and rock properties is reviewed to determine the adequacy of available data; the additional data that will be needed at specific sites; and the critical long-term studies, such as ground water and seismicity, that will be needed and will require advance planning and early action. The data also are used to develop the regional geology as an aid in defining geologic features at preliminary sites. Geologic field reconnaissances should be made at all sites that have potential and should include examination of important geologic features and potential problem areas identified during office studies. As suggested in Chapter 2, preliminary geologic models (item 16) should be developed for each site indicating possible locations and types of geologic features that would control the selection of project features. Preliminary geologic, seismic, hydrologic, and economic studies should be used to indicate the most favorable sites before preliminary subsurface investigations are started. Proper coordination and timing of these studies can minimize costs and maximize confidence in the results.

Section I. Coordination and Information Collection

3-2. Interagency Coordination and Cooperation. Sources of background information available from other organizations can have a substantial influence on project economy, safety, and feasibility. During initial investigations, project geologists may be unfamiliar with both the regional and local geology. Limited funds must be allocated to many diverse areas of study (e.g., economics, real estate, environment, hydrology, and geology). For these reasons, contacts should be made with federal, state, and local agencies to identify available sources of existing geologic information applicable to the project. A policy of formal coordination with the U. S. Geological Survey (USGS) has been established as outlined below. In addition, informal coordination should be maintained with state geological surveys since critical geologic data and technical information are often available from these agencies. Other organizations listed below may also provide valuable information.

a. Coordination with USGS. The 27 October 1978 Memorandum of Understanding (MOU) with the USGS and implementing instructions in ER 1110-1-1400 provide for exchange of information to assure that all geologic features are considered in project planning and design. The MOU outlines three main activities:

(1) The USGS provides the Corps with existing information and results of research and investigations of regional and local geology, seismology, and hydrology relevant to site selection and design.

(2) The USGS advises the Corps on geologic, seismologic, and hydrologic processes where knowledge is well developed and on specific features of site and regional problems.

(3) The Corps provides the USGS with geologic, seismologic, and hydrologic data developed from Corps studies.

The MOU requires that the USGS be notified in writing when planning studies are to be initiated at a new site or reinitiated at a dormant project. The notification should specify the location of interest and identify specific geologic, seismologic, and hydrologic considerations for which information is needed.

b. Other Organizations. Contacts and visits to offices of the following organizations can produce valuable geotechnical information in the form of published maps and reports and unpublished data from current projects.

(1) Federal Agencies.
(a) Department of Agriculture.
- Forest Service
- Soil Conservation Service
(b) Department of Energy.
- Alaska Power Administration
- Albuquerque Operations Office
- Bonneville Power Administration Office
- Idaho Operations Office
- Nevada Operations Office
- Oak Ridge Operations Office
- Richland Operations Office
- San Francisco Operations Office
(c) Department of Interior.
- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Mines
- Bureau of Reclamation
- Fish and Wildlife Service
- Geological Survey
- National Park Service
(d) Department of Transportation, Federal Highway Administration regional and state division offices.

(e) Environmental Protection Agency regional offices.
(f) Nuclear Regulatory Commission.
(g) Tennessee Valley Authority.

(2) State Agencies.
(a) Geological Surveys and Departments of Natural Resources.
(b) Highway Departments.

(3) Municipal engineering and water services offices.

(4) State and private universities (geology and civil engineering departments).

(5) Private mining, oil, gas, sand, and gravel companies.

(6) Geotechnical engineering firms.

(7) Professional society publications.

3-3. Survey of Available Information. Information and data pertinent to the project can be obtained from a careful search through published and unpublished papers, reports, maps, records, and consultations with the USGS, state geologic and geotechnical agencies, and other federal, state, and local agencies. This information must be evaluated to determine its validity for use throughout the project's development. Deficiencies and problems must be identified early so that studies for obtaining needed information can be planned to assure economy of time and money. Table 3-1 summarizes the sources of topographic, geologic, and special maps and geologic reports.

Section II. Map Studies and Remote Sensing Methods

3-4. Map Studies. Various types of published maps, such as topographic, geologic, mineral resource, soils, and special miscellaneous maps, can be used to obtain geologic information and develop regional geology prior to field reconnaissance and exploration work. The types of available maps and their uses are described in item 44.

a. Topographic Maps. Topographic maps provide information on landforms, drainage patterns, slopes, locations of prominent springs and wet areas, quarries, man-made cuts (for field observation of geology), and mines. If older topographic maps are available, especially in mining regions, abandoned shafts, filled surface pits, and other features can be defined by comparison with later maps.

(1) Optimum use of topographic maps involves the examination of large- and small-scale maps. Certain features, such as large geologic structures, may be apparent on small-scale maps only. Conversely, the interpretation of active geomorphic processes will require accurate, large-scale maps with a small contour interval. As a general rule, the interpretation of topographic maps should proceed from small-scale (large area) maps through intermediate-scale maps to large-scale (small area) maps as the geologic investigation proceeds from the general to the specific.

Table 3-1. Sources of Geologic Information

Agency	Type of Information	Description	Remarks
USGS	Topographic maps	U. S. 7.5-minute series 1:24,000 (supersedes 1:31,680) complete for 13 states Puerto Rico 7.5-minute series 1:20,000 (supersedes 1:30,000) Virgin Island 1:24,000 series. U. S. 15-minute series 1:62,500 (1:63,360 for Alaska) U. S. 1:100,000-scale series (quadrangle, county, or regional format) U. S. 1:50,000-scale county map series U. S. 1:250,000-scale series (Alaska Reconnaissance series being replaced by more accurate Alaska 1:250,000-scale series	Orthophotoquad monocolor maps also produced in 7.5-minute and 15-minute series. New index of maps for each state started in 1976. Status of current mapping from USGS regional offices and in monthly USGS bulletin, "New Publications of the U. S. Geological Survey"
USGS	Geologic maps and reports	1:24,000 (1:20,000 Puerto Rico),1:62,500, 1:100,000, and 1:250,000 quadrangle series includes surficial bedrock and standard (surface and bedrock) maps with major landslide areas shown on later editions 1:500,000 and 1:2,500,000 (conterminous U. S., 1974)	New index of geologic maps for each state started in 1976. List of geologic maps and reports for each state published periodically
USGS	Miscellaneous maps and reports	Landslide susceptibility rating, swelling soils, engineering geology, water resources, and ground water	Miscellaneous Investigation Series and Miscellaneous Field Studies Series, maps and reports, not well cataloged; many included as open file reports
USGS	Special geologic maps	1:7,500,000 on: Karst topography and related terrain, areas of soils; areas of possible landslides; present and proposed nuclear reactor sites; surficial clay, sand, silt, and gravel deposits; areas subject to volcanic hazards; streams with flow rates expansive of 300 cu. ft/sec or greater	Prepared in preliminary form (1979) under USGS National Environmental Overview Program
USGS	Special maps	1:7,500,000 and 1:1,000,000: Limestone Resources, Solution Mining Subsidence, Quaternary Dating Applications, Lithologic Map of U. S., Quaternary Geologic Map of Chicago, Illinois, and Minneapolis, Minnesota areas	
USGS	Hydrologic maps	Hydrologic Investigations Atlases with a principal map scale of 1:24,000; includes water availability, flood areas, surface drainage precipitation and climate, geology, availability of ground and surface water, water quality and use, and streamflow characteristics	Some maps show groundwater contours and location of wells
USGS	Earthquake hazard	Seismic maps of each state (started in 1978 with Maine); field studies of fault zones; relocation of epicenters in eastern U. S.; hazards in the Mississippi Valley area; analyses of strong ground motion data; state-of-the-art workshops	Operates National Strong-Motion Network and National Earthquake Information Service publishes monthly listing of epicenters (worldwide)
USGS	Mineral resources	Bedrock and surface geologic mapping; engineering geologic investigations; map of power generating plants of U. S. (location of built, under construction, planned, and type); 7.5-minute quadrangle geologic maps and reports on surface effects of subsidence into underground mine openings of eastern Powder River Basin, Wyoming	
USGS	Bibliography	"Bibliography of North American Geology" North American, Hawaiian Islands, and Guam	Published until 1972
Geological Society of America	Bibliography	"Bibliography and Index of Geology Exclusive of North America" "Bibliography and Index of Geology"	1934-1968 1969 to present, 12 monthly issues plus yearly cumulative index ($600/year)
NOAA	Earthquake hazards	"Earthquake History of the U. S." Earthquake list and computer-printed epicenter maps	
NASA	Remote sensing data	Landsat, skylab imagery	See Table 4-2 of EP 70-1-1 for detailed information

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Table 3-1. (Concluded)

Agency	Type of Information	Description	Remarks
USGS	Flood-prone area maps	1:24,000 series maps outlining floodplain areas not included in Corps of Engineers reports or protected by levees	Stage 2 of 1966 89th Congress House Document 465
USAEWES	Earthquake hazard	"State-of-the-Art for Assessing Earthquake Hazards in the United States," Miscellaneous Paper S-73-1	Series of 19 reports, 1973 to present
International Union of Geological Societies	Worldwide mapping	Commission for the Geological Map of the World publishes periodic reports on worldwide mapping in "Geological Newsletter"	
SCS	Soil survey reports	1:15,840 or 1:20,000 maps of soil information on photomosaic background for each county. Recent reports include engineering test data for soils mapped, depth to water and bedrock, soil profiles grain-size distribution, engineering interpretation and special features. Recent aerial photo coverage of many areas	Reports since 1957 contain engineering uses of soils mapped, parent materials, geologic origin, climate, physiographic setting, and profiles
State Geologic Agencies	Geologic maps and reports	State and county geologic maps; mineral resource maps; special maps such as for swelling soils; bulletins and monographs; well logs; water resources, groundwater studies	List of maps and reports published annually, unpublished information by direct coordination with state geologist
Defense Mapping Agency (DMA)	Topographic maps	Standard scales of 1:12,500, 1:50,000, 1:250,000 and 1:1,000,000 foreign and worldwide coverage including photomaps	Index of available maps from DMA
American Association of Petroleum Geologists	Geological highway map series	Scale approximately 1 inch equal to 30 miles shows surface geology and includes generalized time and rock unit columns, physiographic map, tectonic map, geologic history summary, and sections	Published as 12 regional maps including Alaska and Hawaii
TVA	Topographic maps, geologic maps and reports	Standard 7.5-minute TVA-USGS topographic maps, project pool maps, large-scale topographic maps of reservoirs, geologic maps and reports in connection with construction projects	Coordinate with TVA for available specific information
USBR	Geologic maps and reports	Maps and reports prepared during project planning and design studies	List of major current projects and project engineers can be obtained. Reports on completed projects by interlibrary loan or from USAE Waterways Experiment Station for many dams
USGS National Cartographic Information Center	Aerial photographic coverage	Aerial Photographic Summary Record System provides sources of planned, in progress, and existing aerial photography in eight categories	

(2) Certain engineering geology information can be inferred from topographic maps by proper interpretation of landforms and drainage patterns. Topography tends to reflect the geologic structure and composition of the underlying rocks and the geomorphic processes acting on them. The specific type of geomorphic processes and the length of time they have been acting on the particular geologic structure and rock type will control the degree to which these geologic features are evident on the topographic maps. Geologic features are not equally apparent on all topographic maps, and considerable skill and effort are required to

arrive at accurate geologic interpretations. Information of engineering significance that may be obtained or inferred from topographic maps includes physiography, general soil and rock types, bedrock structure, and geomorphic history.

b. Geologic Maps. Surficial and bedrock geologic maps can be used in developing formation descriptions, formation contacts, gross structure, fault locations, and approximate depths to bedrock (item 48). Maps of 1:250,000 scale or smaller are suitable for the development of regional geology since they can be used with remote sensing imagery of similar scale to refine regional geology and soils studies.

c. Mineral Resource Maps. Mineral resource maps produced by the USGS and state geological services are important sources of geologic information. For example, the USGS coal resources evaluation program includes preparation of geologic maps (7.5-min quadrangle areas) to delineate the quantity, quality, and extent of coal on federal lands. The USGS and state geologic service maps provide information on oil and gas lease areas and metallic mineral resource areas. Mineral resource maps also include information on natural construction materials such as quarries and sand and gravel deposits. These maps can be used in estimating the effects of proposed projects on mineral resources (such as access for future recovery, or reduction in project costs by recovery during construction).

d. Hydrologic and Hydrogeologic Maps. Maps showing hydrologic and hydrogeologic information provide a valuable source of data on surface drainage, well locations, ground-water quality, ground-water level contours, seepage patterns, and aquifer locations and characteristics.

3-5. Remote Sensing Methods. Conventional aerial photographs and various types of imagery can be used effectively for large-scale regional interpretation of geologic structure, analyses of regional lineaments, drainage patterns, rock types, soil characteristics, erosion features, and availability of construction materials. Geologic hazards, such as faults, fracture patterns, subsidence, and sink holes or slump topography, can also be recognized from air photo and imagery interpretation. Side-looking airborne radar (SLAR) provides illumination of the surface topography from low angles and from various directions, and can accentuate regional geologic structure. In addition, SLAR has the capability of penetrating cloud cover, giving it the ability to obtain images when desired, day or night and independent of seasonal changes in solar lighting. Guidance in obtaining available photographic and imagery data, interpretation, and planning for new coverage are contained in EP 70-1-1. This publication discusses special interpretation techniques and sources of commercial services.

Section III. Field Reconnaissance and Observations

3-6. Field Reconnaissance. After a complete review of available geotechnical data, a geologic field reconnaissance should be made to gather information that can be obtained without subsurface explorations or detailed study. It is desirable that the geological field reconnaissance be conducted as part of a multidisciplined effort. The composition of a team would depend upon the type and size of the project, the project effect on the area in question, and on any special problems identified as a result of early office studies. The team should include engineering geologists, soils engineers, planning engineers, and representatives of other disciplines as appropriate.

3-7. Observations. Observations made during field reconnaissances can be divided into four categories:

- Geologic/hydrologic features and geologic hazards to confirm, correct, or extend those developed during early office studies, and the preparation of regional geologic maps.
- Site accessibility, ground conditions, and right-of-entry problems that would affect field exploration work.
- Cultural features that could affect the project and exploration work.
- Condition of existing structures and construction practices that would indicate problem soil and rock conditions.

a. Observations of geologic features should include rock outcrops and soil exposures to verify or extend available geologic maps. The strike and dip of major joint sets and evidence of joint sheeting or steeply dipping beds that would affect the stability of natural or excavated slopes should also be noted. Table 3-2 outlines special geologic features and conditions which should be considered. The location of sources of construction materials, such as sand and gravel deposits, borrow areas for soils, and active or abandoned quarries, are also important. Observable hydrologic features include surface drainage flow, springs and seeps in relation to formation members, and marshy or thick vegetation areas indicating high ground-water tables.

b. Cultural features, such as the location of powerlines, pipelines, access routes, and ground conditions that could restrict the location of or access to borings, should be noted. Sources of water for early exploratory work and for project construction should be determined. Local construction practices and the condition of existing structures and roads should be observed and potential problems noted.

c. Field observations have special value in planning subsequent investigations and design studies because adverse subsurface conditions often can be anticipated from surface evidence and the regional geology. Suitable alternatives for foundation or structure types may be suggested by comprehensive field observations.

d. Field reconnaissance can emphasize the need for new mapping and new aerial photographic coverage. Such coverage should be coordinated with planners early in the study process to insure sufficient and timely coverage.

Section IV. Information Developed

3-8. Summary. Compiled and properly interpreted regional geology data, coupled with information obtained during field reconnaissances, will provide the information necessary to identify suitable sites and to determine the scope of site investigations. The completion of Regional Geology and Site Reconnaissances Studies should result in the following:

- Regional geologic conditions identified and incorporated into a regional geologic map.

  Preliminary assessment made of regional seismicity, tentative location of sources of construction materials.

- Tentative models developed of geologic conditions at suitable sites.

- Input developed for Environmental Impact Statement.

Table 3-2. Special Geologic Features and Conditions Considered in Office Studies and Field Observations

Geologic Feature or Condition	Influence on Project	Office Studies	Field Observations	Questions to Answer
Landslides	Stability of natural and excavated slopes	Presence or age in project area or at construction sites should be determined Compute shear strength at failure. Do failure strengths decrease with age of slopes--especially for clays and clay shales?	Estimate areal extent (length and width) and height of slope Estimate ground slope before and after slide (may correspond to residual angle of friction) Check highway and railway cuts and deep excavations, quarries and steep slopes	Are landslides found off site in geologic formations of same type that will be affected by project construction? What are probable previous and present groundwater levels? Do trees slope in an unnatural direction?
Faults and faulting; past seismic activity	Of decisive importance in seismic evaluations; age of most recent fault movement may determine seismic design earthquake magnitude	Determine existence of known faults and fault history from available information Examine existing boring logs for evidence of faulting from offset of strata	Verify presence at site, if possible, from surface evidence; check potential fault traces located from aerial imagery Make field check of structures, cellars, chimneys, roads, fences, pipelines, known faults, caves, inclination of trees, offset in fence lines	Are lineaments or possible fault traces apparent from regional aerial imagery?
Stress relief cracking and valley rebounding	Valley walls may have cracking parallel to valley. Valley floors may have horizontal cracking. In some clay shales stress relief from valley erosion or glacial action may not be complete	Review pertinent geologic literature and reports for the valley area. Check existing piezometer data for abnormally low levels in valley sides and foundation; compare with normal groundwater levels outside valley	Examine wells and piezometers in valleys to determine if levels are lower than normal groundwater regime (indicates valley rebound not complete)	
Sinkholes; karst topography	Major effect on location of structures and feasibility of potential site (item 13)	Examine air photos for evidence of undrained depressions	Locate depressions in the field and measure size depth and slopes. Differences in elevation between center and edges may be almost negligible or many feet. From local residents, attempt to date appearance of sinkhole	Are potentially soluble rock formations present such as limestone, dolomite, or gypsum? Are undrained depressions present that cannot be explained by glaciation? Is surface topography rough and irregular without apparent cause?
Anhydrates or gypsum layers	Anhydrates in foundations beneath major structures may hydrate and cause expansion, upward thrust and buckling Gypsum may cause settlement, subsidence, collapse or piping. Solution during life of structure may be damaging	Determine possible existence from available geologic information and delineate possible outcrop locations	Look for surface evidence of uplift; seek local information on existing structures Check area carefully for caves or other evidence of solution features	Are uplifts caused by possible hydrite expansion or "explosions"?
Caves	Extent may affect project feasibility or cost. Can provide evidence regarding faulting that may relate to seismic design. Can result from unrecorded mining activity in the area		Observe cave walls carefully for evidence of faults and of geologically recent faulting. Estimate age of any broken stalactites or stalagmites from column rings	Are any stalactites or stalagmites broken from apparent ground displacement or shaking?

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(Sheet 1 of 3)

Table 3-2. (Continued)

Geologic Feature or Condition	Influence on Project	Office Studies	Field Observations	Questions to Answer
Erosion resistance	Determines need for total or partial channel slope protection	Locate contacts of potentially erosive strata along drainage channels	Note stability of channels and degree of erosion and stability of banks	Are channels stable or have they shifted frequently? Are banks stable or easily eroded? Is there extensive bank sliding?
Internal erosion	Affects stability of foundations and dam abutments. Gravelly sands or sands with deficiency of intermediate particle sizes may be unstable and develop piping when subject to seepage flow	Locate possible outcrop areas of sorted alluvial materials or terrace deposits	Examine seepage outcrop areas of slopes and riverbanks for piping	
Area subsidence	Area subsidence endangers long-term stability and performance of project	Locate areas of high groundwater withdrawal, oil fields and subsurface solution mining or underground mining areas	Check project area for new wells or new mining activity	Are there any plans for new or increased recovery of subsurface water or mineral resources?
Collapsing soils	Determines need for removal of shallow foundation materials that would collapse upon wetting	Determines how deposits were formed during geologic time and any collapse problems in area	Examine surface deposits for voids along eroded channels, especially in steep valleys eroded in fine-grained sedimentary formations	Were materials deposited by mud flows?
Locally lowered ground water	May cause minor to large local and area settlements and result in flooding near rivers or open water and differential settlement of structures	Determine if heavy pumping from wells has occurred in project area; contact city and state agencies and USGS	Obtain groundwater levels in wells from owners and information on withdrawal rates and any planned increases. Observe condition of structures. Contact local water plant operators	
Abnormally low pore water pressures (lower than anticipated from groundwater levels)	May indicate effective stresses are still increasing and may cause future slope instability in valley sites	Compare normal groundwater levels with piezometric levels if data is available		Is a possible cause the past reduction in vertical stresses (e.g. deep glacial valley or canal excavations such as Panama Canal in clay shales where pore water pressures were reduced by stress relief)?
In situ shear strength from natural slopes	Provides early indication of stability of excavated slopes or abutment, and natural slopes around reservoir area	Locate potential slide areas. Existing slope failures should be analyzed to determine minimum in situ shear strengths	Estimate slope angles and heights, especially at river bends where undercutting erosion occurs. Determine if flat slopes are associated with mature slide or slump topography or with erosion features	Are existing slopes consistently flat, indicating residual strengths have been developed?
Swelling soils and shales	Highly preconsolidated clays and clay shales may swell greatly in excavations or upon increase in moisture content	Determine potential problem and location of possible preconsolidated strata from available information	Examine roadways founded on geologic formations similar to those at site. Check condition of buildings and effects of rainfall and watering	Do seasonal groundwater and rainfall or watering of shrubs or trees cause heave or settlement?

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(Sheet 2 of 3)

Table 3-2. (Concluded)

Geologic Feature or Condition	Influence on Project	Office Studies	Field Observations	Questions to Answer
Varved clays	Pervious layers may cause more rapid settlement than anticipated. May appear to be unstable because of uncontrolled seepage flow through pervious layers between overconsolidated clay layers or may have weak clay layers. May be unstable in excavations unless well points are used to control ground water	Determine areas of possible varved clay deposits associated with prehistoric lakes. Determine settlement behavior of structures in the area	Check natural slopes and cuts for varved clays; check settlement behavior of structures	
Dispersive clays	A major factor in selecting soils for embankment dams and levees	Check with Soil Conservation Service and other agencies regarding behavior of existing small dams	Look for peculiar erosional features such as vertical or horizontal cavities in slopes or unusual erosion in cut slopes. Perform "crumb" test (item 32)	
Riverbank and other Liquefaction areas	Major effect on riverbank stability and on foundation stability in seismic areas	Locate potential areas of loose fine-grained alluvial or terrace sands; most likely along riverbanks where loose sands are present and erosion is occurring	Check riverbanks for scallop-shaped failure with narrow neck (may be visible during low water). If present, determine shape, depth, average slope and slope of adjacent sections. Liquefaction in wooded areas may leave trees inclined at erratic angles. Look for evidence of sand boils in seismic areas	
Filled areas	Relatively recent filled areas would cause large settlements. Such fill areas may be overgrown and not detected from surface or even subsurface evidence	Check old topo maps if available for depressions or gullies not shown on more recent topo maps	Obtain local history of site from area residents	
Local overconsolidation from previous site usage	Local areas of a site may have been overconsolidated from past heavy loadings of lumber or material storage piles		Obtain local history from residents of area	

(Sheet 3 of 3)